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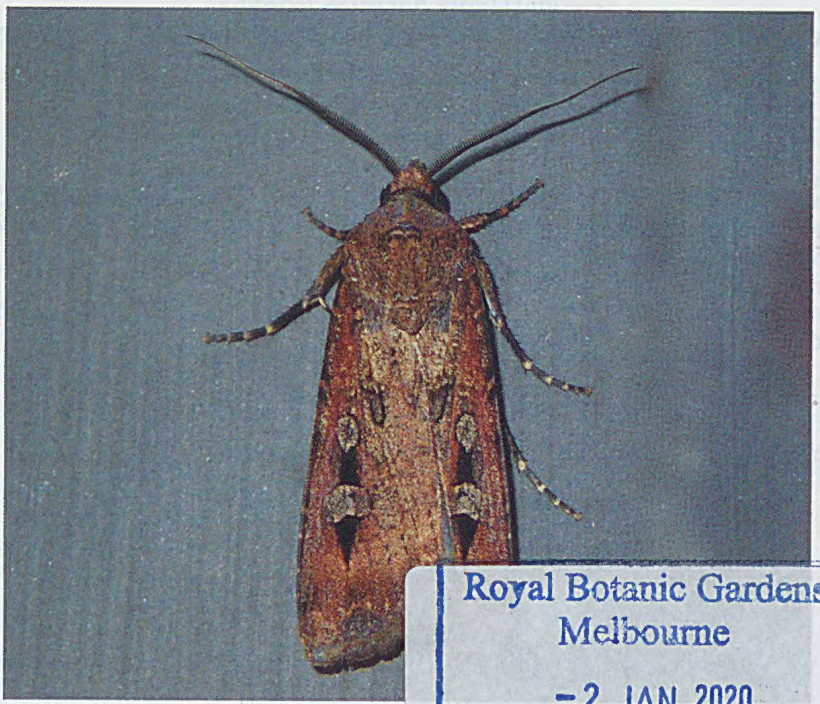

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Postal Address: FNCV, PO Box 13, Blackburn, Victoria 3130, Australia.
Phone +61 (03) 9877 9860; email: admin@fncv.org.au
www.fncv.org.au

Patron: The Governor of Victoria

Address correspondence to:
The Editors, *The Victorian Naturalist*, PO Box 13, Blackburn, Victoria 3130, Australia.
Phone: (03) 9877 9860. Email: vicnat@fncv.org.au

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The Victorian Naturalist

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Front cover: Bogong Moth *Agrotis infusa*. Photo John Eichler.

Bogong Moths *Agrotis infusa*, soil fertility and food chains in the Australian alpine region, and observations concerning the recent population crash of this iconic species

Ian Mansergh[1] and Dean Heinze [2]

[1] Research Centre for Applied Alpine Ecology, La Trobe University, Bundoora, Victoria 3084
[2] Ecologist, Collinsvale, Tasmania 7012

Abstract
Bogong Moths *Agrotis infusa* and their summer sub-adult migration (up to 1000 km) to the Alps is an important natural and cultural (Indigenous and European) phenomenon in south-east Australia. In Victoria, high elevation rock outcrops and peri-glacial boulder fields are favoured aestivation sites for the moths. A variety of mammalian and avian predators exploit this nutrient rich food source. The summer of 2017 saw an unprecedented collapse in the annual numbers of moths migrating to the Alps. They have not returned in large numbers everywhere.

Investigations into the Mountain Pygmy-possum *Burramys parvus* included a study of the contribution of *A. infusa* to boulder field habitats in Victoria (basalt) and NSW (granite). Standardised soil and litter samples (n= 132) were collected in three altitude bands and from eastern and western aspects. *Agrotis infusa* favoured high altitude westerly slopes and there was a very high correlation with *B. parvus* abundance (R= 0.9087). Primary and secondary bio-transport of *A. infusa* (remains and guano) make a significant contribution to alpine food chains, nutrient dispersal and soil fertility. These data and 40 years of annual observations that include the recent population collapse have dramatic implications for the alpine environment. No gross environmental changes that may have been adverse to *Agrotis infusa* have been observed at alpine aestivation sites, strongly suggesting unprecedented detrimental change (climate or human-induced) across its natal areas in south-east Australia. Apart from severe drought, we suspect adverse land-use changes, including increased use of neonicotinoids. Systematic and robust monitoring and research into this continental-scale collapse of the Bogong Moth is urgently required. (*The Victorian Naturalist* **136** (6), 2019, 192–202)

Keywords: *Burramys parvus*, insect migration, bio-transport, alpine trophic levels, alpine nutrients

Introduction

The annual migration of Bogong Moths *Agrotis infusa* to the alpine region is an important ecological and cultural (Indigenous and European) natural phenomenon in south-east Australia. Such is the magnitude of this concentrated food resource that Indigenous groups seasonally migrated to the alpine region to exploit it (Flood 1980). Its periodic invasions of Parliament House in Canberra, and its presence at the Sydney Olympic Games (2000), have added to the iconic status of the species. In the Alps, caves and interstitial spaces in peri-glacial boulder fields and rock outcrops are favoured aestivation sites and a variety of mammalian and avian predators exploit the concentrations of moths and disperse nutrients across the alpine environment. The moth is also a major component of the diet of the endangered Mountain Pygmy-possum *Burramys parvus*, particularly breeding and lactating females, when it may be the exclusive prey (Mansergh *et al.* 1990; Smith and Broome 1992).

Common (1954) published the first comprehensive biological study on the species, augmented in Common (1989), and Green (2011) estimated the amount of nutrients and their energy content that *A. infusa* brought to the Snowy Mountains. Warrant *et al.* (2016) provide a current review. In the alluvial plains of south-east Australia a female may lay c. 2000 eggs and is capable of multiple broods within a season (Common 1954; Warrant *et al.* 2016). *Agrotis infusa* spend the autumn-winter in their egg-pupae stage (as cutworms) and are recognised as an agricultural pest, feeding on crops of annual dicotyledons and broad-leafed crops (Common 1954). As a sub-adult, the moth is c. 25 mm long, and the annual migration (up to 1000 km) to the Alps in late September–November is accomplished by exploiting the prevailing NW winds and their recently discovered internal magnetic-assisted navigation, the first insect known to exhibit this attribute (Dreyer *et al.* 2018). On arrival in the Alps, a

moth weighs about 0.33 g (dry weight 0.155 g) and its abdomen contains 57% fat (dry weight) in females and 66% in males (Common 1954; Green 2011). Green (2011) found the gross energy content per moth to be 4.86 KJ and estimated they bring a massive 4929 GJ of energy to the Snowy Mountains.

Despite its iconic status as an agricultural 'pest' and its role as a key dietary item for the endangered *B. parvus*, there has been no systematic monitoring of *A. infusa* abundance: perhaps the moth migration was perceived as 'too big to fail'. However, the need for such information has been identified in national and state recovery documents for *B. parvus* (e.g. Department of Environment, Land, Water and Planning 2016). Consequently, information about annual variation in moth numbers (in natal and alpine areas) is derived mostly from anecdotal observations and limited surveys. Good and poor seasons have been observed but never the collapse noted in 2017.

From our first observations in 1978 and probably for millennia, sounds from *B. parvus* habitat in Victorian boulder fields could be heard from over a kilometre away—large flocks of Little Ravens *Corvus mellori* and currawongs *Strepera* spp. called as they fed on the moths. In 2017–19, there was an unprecedented dearth of moths. The boulder fields were silent! In spring–early summer of 2017 and 2018, widespread loss of pouch young litter was observed (DH) in *B. parvus* populations due to starvation. This was unprecedented (never a single incidence in more than 10 000 observations) in 40 years of annual monitoring.

Here we present data collected on *A. infusa* in alpine boulder fields (Victoria and NSW) during a PhD study on *B. parvus* (Mansergh 1988, Box 1). The study sought to quantify the contributions of the moths to: (a) *B. parvus* populations; (b) alpine soil fertility within boulder fields; and (c) the scale of nutrient transfer to food chains in the alpine region. Given the collapse of *A. infusa* migration to the Alps (breeding failure, lack of juvenile recruitment), these data are augmented with observations of *B. parvus* sites monitored over a 41-year period in an effort to highlight little-studied implications of moth decline for the health of alpine ecosystems. We trust this will contribute to understanding the urgent need for further research and monitoring.

Box 1. Interstitial spaces in granite and basalt boulder fields

Bogong moths *Agrotis infusa* seek cool, sheltered microclimates for aestivation in the alpine region. Caves and interstitial spaces in boulder fields provide such habitat. The geomorphology of boulder fields of granite (NSW) and basalt (Victoria) provide different types and amounts of sheltering sites that affect *A. infusa* abundances. Peri-glacial freezing and thawing exploited fractures in outcropping basalt, characteristically breaking angular blocks 0.3–0.6 m (longest axis) that formed boulder fields to depths of > 4 m. Interstitial spaces may be 30–50% of the volume (N Rosengren, pers. comm., October 2019). Mountain plum-pine *Podocarpus lawrencei* establishes when the boulder fields are c. 2 m deep and, as soil and litter accumulates, a unique ecological vegetation community of *P. lawrencei* heathland evolves (see Gullan and Norris 1984). Granite boulder fields support *P. lawrencei* heathland but typically have larger rounded boulders (remnant corestones 2–3 m) resulting in relatively fewer interstitial spaces than for basalt boulder fields (Fig. 1A/1B; Mansergh and Broome 1994).

Methods

The broad study area is the Bogong and Hotham High Plains in Victoria's alpine region (Fig. 2). Details (maps, photographs, grid sites) of specific collection locations, including those in NSW, are provided in Mansergh (1988) (digitised—http://hdl.handle.net/1959.9/567012) and in Mansergh and Broome (1994). Our soil samples were collected within basalt boulder fields where their depth was between 0.5 and 1.0 m—litter was deep and moist. In granite boulder fields, soil samples were collected at the base of boulders—litter was less abundant than in the basalt sites.

A. Soil fertility and organic matter

A sample consisting of 10 two-cm diameter cores of soil was taken to depths of 25 mm and

Fig. 1A. Bogong Moths *Agrotis infusa* in basalt boulder field at Mt Higginbotham, November 1987. The aggregations were 100 mm deep and there were so many moths that those photographed were forced into non-favoured sunlight exposed roosts. Photo Ian Mansergh.

Fig. 1B. Deep basalt boulder fields on Mt Loch looking eastward. In foreground, note the structure providing abundant, sheltered interstitial spaces used as aestivation sites by *Agrotis infusa*. *Podocarpus* heathland in mid-ground is the optimal habitat of *B. parvus* (see Box 1). Photo Dean Heinze, 2018.

100 mm over an area of approximately 10 m^2 within 3 m of known *B. parvus* capture sites. At each site, three samples were taken at altitudes above 1760 m on both western and eastern aspects. Samples were collected in February 1985 on Mt Higginbotham, Victoria (basalt), and in February 1986 in Kosciuszko National Park, NSW (granite) (hereafter KNP—western aspect Charlottes Pass; eastern aspect Upper–Lower Blue Cow). Basalt boulder fields were 0.3 m deep at the margins and were often > 3 m deep in the centre. In contrast, granite boulder fields had a tor structure with much more limited interstitial spaces (Box 1; photographs of

Fig. 2. Basalt and other boulder fields in the Victorian alpine region (above 1200 m, between Mt Bogong and Mt Higginbotham) showing localities of persistent Mountain Pygmy-possum *B. parvus* populations. Image Neville Rosengren.

sites in Mansergh 1988; Mansergh and Broome 1994). Samples were examined by the (then) State Chemistry Laboratory of Victoria (SCLV) using standard tests for: potassium (K); Phosphorus (P); pH value and oxidisable carbon. A state-wide context was provided by AT Brown (pers. comm., SCLV, 1986: full text in Mansergh 1988).

B. Abundance of* Agrotis infusa *in litter at different aspects and altitudes

In each of three altitude bands (1600–1650 m, 1650–1750 m, and ≥ 1780 m) on both easterly and westerly aspects of Mt Higginbotham, six 15 × 15 × 2 cm litter samples were collected in February 1985. Sites were chosen along *B. parvus* trapping lines (visited ≥ 7 times) where *A. infusa* were most abundant. Each collection site was within the boulder field, at the base of boulders, and was at least 2 m distant from any other. In one instance (westerly site lowest altitude) a trapping site was not available. Similarly, in February 1986, samples were collected in KNP

at sites used in Method section A (above), and a single high altitude westerly site on Mt Bogong (Victoria). All samples were examined and all wings and anatomical parts counted. A minimum number of moths was estimated from the larger count, by dividing major wings by two or the number of all wings by four.

These data were analysed with *B. parvus* abundances at the same sites (mean number per visit up to June 1985—*B. parvus* trapping records). The association between *A. infusa* and *B. parvus* counts was examined using the product-movement correlation coefficient calculated from its six pairs of transformed values from sites with a wide range of *A. infusa* counts.

C. Accumulation of* Agrotis infusa *over time

A masonite board (15 × 15 cm) was placed on the ground at six sites systematically chosen within each of 11 *Burramys* trapping replicates (each 0.2 ha) on Mt Higginbotham (n= 66: 18 west and 48 east). Boards were visited between November 1984 and January 1986 and litter and *A. infusa* debris collected.

D. Observations of fauna in boulder fields 1978–2019

Apart from studies reported here, the abundance of *A. infusa* was not studied or monitored in Victoria as the sheer regularity of the abundance of the species indicated (wrongly as it turns out) that it was unlikely to be a limiting factor in the abundance of *B. parvus*, recognising the natural differences between the basalt habitats of Victoria and those of granite in NSW. Notwithstanding, during the annual *B. parvus* monitoring program (> 20 days and > 4000 trap-nights p.a.) good and poor years for *A. infusa* were generally noted; observations on the general health of the habitat and mammalian and other faunal abundance and use were made (e.g. Mansergh and Broome 1994; Heinze *et al.* 2004).

Results

A. Soil fertility and organic matter

The results of the six soil parameters examined are provided in Table 1. Both sites had high levels of total nitrogen (0.57–1.81%) and organic carbon (9.7–27.2%). Basalt-derived soils are inherently more fertile than those from derived granite: however, the aestivation of *A. infusa* in Victorian basalt boulder fields makes soil fertility significantly richer than granite soils in every nutrient (N, K, P and Oxidisable C) measured (Table 1). *Agrotis infusa* formed a large portion of the organic residue at Mt Higginbotham, whereas in KNP most organic residue was of vegetation alone (Table 1). In general, as expected, the 0.25 mm samples have a higher K, P, N, and C than the 0–100 mm samples at both sites, except for available P at Mt Higginbotham, which was similar at both depths (Table 1). Due to the abundance of *A. infusa* remains (see Methods section B), Mt Higginbotham soils are more fertile than KNP soils, especially in relation to available P, which is very high in the former locality but marginal at KNP.

B. Abundance of* Agrotis infusa *in litter at different aspects and altitudes

Agrotis infusa remains were markedly more common in basalt than granite sites. The total number of moths collected at Mt Bogong (12 on granite) and in KNP (23) provided insufficient data for analysis. In contrast, *A. infusa* remains were recorded at 14 000 per m^2 at one site in the high-altitude basalt boulder field of Mt Higginbotham. After a variance-stabilising transformation to logarithms, a two-way analysis of variance of the 36 samples showed that the frequency of *A. infusa* varied with both altitude and aspect (interaction effect $F = 4.57$ on 2 and 30 D.F., $P < 0.02$) (Table 2). High altitude westerly aspects were favoured (Table 2) whilst there appeared to be little difference between aspects at lower altitudes (< 1650 m), although it is suspected that this is due to the relative paucity of *A. infusa* generally at this altitude (Table 2). There is a very strong positive association between the abundances of *A. infusa* and *B. parvus* ($r = 0.9087$, $P < 0.01$, Fig. 3).

As remains (dead moths) were recorded at 14 000 per m^2 (using only samples to 25 mm depth) and, at higher altitudes, nutrient availability remains similar down to 100 mm due to the moths (Table 1), it is concluded that *A. infusa* bio-transports a most significant nutrient input into the alpine environment.

C. Accumulation of* Agrotis infusa *over time

The method failed to detect moth accumulation over time, probably because of air movement

Table 1. Soil analysis of six standard fertility parameters in *A. infusa* aestivation boulder fields on Mt Higginbotham (Vic) and in Koscuiszko National Park (NSW) (n = 24). Analysis courtesy of State Chemistry Laboratories, Victoria (Brown 1986).

Locality		Altitude (m)	Aspect	Sample Depth[1] (0 mm)	Total Nitrogen[2]	Reaction (pH) (H_2O	$CaCl_2$)	Electrical Conductivity ds/m	Skene (K) Potassium ppm	Olsen P Phosphorous ppm	Oxidisable Carbon (%)
Mt Higginbotham	basalt dark grey-brown peat	1760–1800	West	25	1.81	4.9	4.1	0.16	540	115	23.4
				25	1.47	4.9	4.1	0.12	477	83	19.2
				25	1.78	4.9	4.3	0.10	529	97	23.0
				100	1.36	5.1	4.4	0.08	454	81	16.9
				100	1.55	4.9	4.2	0.10	405	112	19.1
				100	1.46	4.9	4.2	0.09	382	110	17.7
			East	25	1.38	5.6	5.1	0.14	788	71	19.1
				25	1.72	5.8	5.4	0.09	534	63	27.2
				25	1.59	5.0	4.4	0.12	595	71	24.5
				100	1.29	5.8	5.2	0.08	565	76	16.6
				100	1.49	5.1	4.5	0.95[3]	450	64	19.4
				100	1.58	4.8	4.2	0.07	469	64	21.1
Koscuiszko NP	Charlottes Pass granite dark grey-brown peat	1820–1950	West	25	0.75	5.0	4.1	0.06	417	20	12.2
				25	1.06	4.4	4.1	0.08	410	16.5	18.8
				25	0.55	5.0	4.3	0.07	243	13.5	9.7
				100	0.68	4.8	4.1	0.15	307	16.1	9.9
				100	0.75	4.7	4.0	0.08	323	15.7	13.2
				100	0.57	4.9	4.2	0.07	249	12.7	9.3
Koscuiszko NP	Blue Cow granite grey-brown peat	1800–1900	East	25	1.24	4.6	3.9	0.15	387	18.7	17.8
				25	1.11	4.7	3.9	0.08	308	13.2	16.6
				25	0.89	5.1	4.4	0.08	310	11.5	15.2
				100	1.07	4.6	4.2	0.10	330	12.1	15.7
				100	0.90	4.9	4.0	0.08	258	8.2	12.4
				100	1.15	4.6	4.0	0.11	257	9.3	17.0
Significance[4]	–Locality				***		**		***	***	***
	–Aspect						*			***	*
	–Aspect x Locality			**	*				**		
	–Depth								**		*

[1]At Mt Higginbotham *A. infusa* remains up to 50 mm depth (mean 25 mm) plus vegetation residue; at Mt Koscuiszko most organic residue was vegetation alone.
[2]Dumas % method.
[3]Chloride as NaCl in this sample was 0.015% and is a normal, low level.
[4]3-way ANOVA significance levels: *** = < 0.001; ** = < 0.01; * = < 0.05.

Table 2. Log means of the number of *Agrotis infusa* collected at three high altitude bands on westerly and easterly aspects on Mt Higginbotham, January 1985.

Aspect	Altitude band (m)		
	>1750	1750–1650	<1650
West	4.118	2.617	0.5972
East	2.341	1.647	0.1832

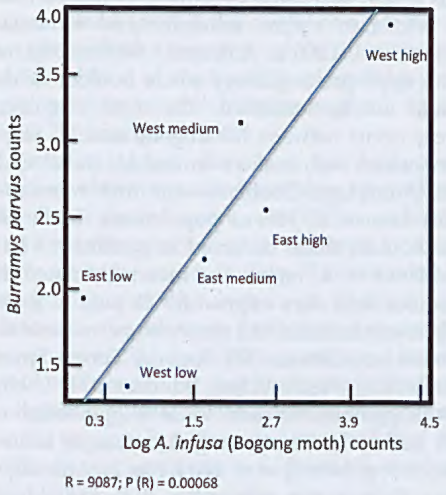

Fig. 3. Regression of the log means of the number of *Agrotis infusa* and number of *Burramys parvus* collected at various altitudes and aspects on Mt Higginbotham, Victoria (January 1985).

and/or animal activity. The boards were visited an average of five times (range 2–7) with 330 total visits over the period. A total of 48 moths were recorded (47 on high western slopes) on 10 occasions (3%). This method is not recommended without refinement.

D. Observations at Agrotis infusa *aestivation boulder fields*

Victorian boulder fields where Agrotis infusa *aestivates:*

1. The arrival time of the moths was usually late September to early October and moths tended to arrive *en masse*, aided by the NW winds. In contrast, the departing period was more extended—segments of the population could begin leaving in mid-February and few moths were observed in the field by mid-April. In still weather, regular sunset flights may have allowed evaluation of the less reliable SE winds to aid return to natal sites.
2. Aestivating moths favour, and help create, a micro-climate out of the wind and sun, hence their attraction to boulder fields and caves. The structure of the deep basalt boulder fields allows three-dimensional aestivation sites, most of which are inaccessible to observation (see Mansergh 1988; Box 1; Fig. 1). However, at many sites and during many years, aestivating moths could be observed 100 mm deep (> depth than index finger) in the interstitial spaces. In November 1987, moth congregations were so large that suboptimal space in afternoon sunlight had to be occupied (Fig. 1). Interstitial spaces (aestivation sites) are 30–50% of the volume of basalt boulder fields (Box 1, Fig 1B). Densities of moths as shown in Fig 1A suggest that a cubic metre of boulder field could support >50 000 aestivating *A. infusa*.
3. Victorian *Agrotis infusa* aestivation sites provide a concentrated food resource for small mammals and support the highest densities of small mammals in any alpine and subalpine environment. These moths are a major component of the spring–summer diets of the Bush Rat *Rattus fuscipes* (frequency in scats > 51 % of scats), Dusky Antechinus *Antechinus swainsonii* (49 %) and *B. parvus* (69 %) (Mansergh 1988; Mansergh *et al.* 1990). Adult female *B. parvus* remain sedentary in these basalt sites, and densities of 95 per ha have been recorded, whereas 24 adults (male and female) per ha is the highest recorded in granite sites (Blue Cow) (Mansergh and Broome 1994). *Agrotis infusa* may be the exclusive prey item of females during breeding in both basalt and granite sites (Mansergh 1988; Smith and Broome 1992; Heinze *et al.* 2004). However, increased abundance of moths in basalt *A. infusa* aestivation sites increases densities of *B. parvus* four-fold compared to the granite sites. High concentrations of moths were also found in Red Fox *Vulpes vulpes* scats.
4. During the day (November–March), flocks of ravens and currawongs (often 50 per ha) feed on the moths, and could be heard from a kilometre away. From 1978 this was a con-

sistent feature of the sites. From 2017 to May 2019 the sites were silent and these species were not observed.

5. Microchiropteran bats were often foraging during the twilight emergence of *A. infusa*. Over several years, a variety of bats has been recorded (heard, trapped) (pers. obs.; Martin Schulz, pers. comm., April 2019) adjacent to the boulder fields. They include Gould's Wattled Bat *Chalinolobus gouldii*, Lesser Long-eared Bat *Nyctophilus geoffroyi* and the White-striped Free-tailed Bat *Austronomus australis*.
6. Although no quantified monitoring of *A. infusa* numbers was undertaken, their numbers were abundant during 'wetter' decades (late 1970 to mid 1990s), but began to lessen after 1998/99 and were substantially diminished during the Millennium Drought up to mid-2010. Notable abundant years recorded for *A. infusa* were: 1978/79, 1979/80, 1982/83, 1985/86, 1986/87 and 2013/14. After the high rainfall years of 2010 and 2011, an exceptional Bogong Moth season occurred in the Alps in the summer of 2013/14. Subsequently, *A. infusa* was very abundant in the Victorian lowlands in the winter of 2014 (G McDonald, pers. comm., October 2019). In the Alps, 2014–16 were low abundance years, with a total collapse in the summer of 2017 that continued yearly to May 2019. Pouch young starvation was first observed at Timms Spur in December 2016 (last population examined late in breeding season) but was widespread in 2017–18.
7. Over the 41-year period, individual and small clusters of *A. infusa* were observed across alpine environments under rocks, rocky outcrops and in various types of vegetation, e.g. heathland.

Discussion

The results emphasise the importance of *A. infusa* for the following reasons: (a) it is an important food source for *B. parvus* and other mammalian and avian species in the alpine region; (b) it brings with it a massive bio-transfer of nutrients (input to the alpine environment); and (c) it has been an abundant resource available to Indigenous peoples over millennia. These highlight the magnitude of the loss to the alpine environment caused by the recent unprecedented collapse in *A. infusa* populations. The significant nutrient transfer from the annual *A. infusa* migration and the geographic extent of basalt boulder fields/rocky outcrops across alpine Victoria (Fig. 2) indicates that *A. infusa* makes a massive input to the soil nutrient health of the region.

From aerial photography, O'Brien and Gowans (1985) identified 1454 ha of boulder fields in Victorian alpine, subalpine and montane areas above 1200 m ASL and a further 350 ha with appropriate geology where boulder fields could not be identified. The most extensive areas occur between Mt Bogong and Mt Higginbotham with outliers around Mt Buller and Mt Wombargo–Cobberas—the first two support known *B. parvus* populations. Many of the boulder fields occurred in patches < 3 ha. Evidence of *A. infusa* was invariably noted at boulder field sites trapped for *B. parvus*, even when unsuccessful. All sites with permanent *B. parvus* populations (Mt Bogong, Timms Spur, Mt McKay, Pretty Valley, Bundarra, Mt Loch, Mt Higginbotham and Little Higginbotham, Mt Buller) had aestivating *A. infusa* in abundance (e.g. Heinze *et al.* 2004; Fig. 2). Although very abundant at aestivation sites, individual and small clusters of *A. infusa* were also observed in small clumps of basalt rocks above 1500 m (Fig. 2).

The presence of *A. infusa* remains, including in scats, make the soils of boulder fields much more fertile than the surrounding landscapes. This is markedly so in basalt boulder fields. The high levels of total nitrogen (0.57–1.81%) and organic carbon (9.7–27.2%) far exceed that for typical 'virgin' bushland (0.1–0.2% and 2–4% respectively, Brown 1986). Kirkpatrick *et al.* (2014) recognised eight soil classes across the mainland alpine area: the variation in the mean extractable P (ppm), excluding soils in bogs (160 ppm) was 6 to 45 ppm; total N (%)—1.2 to 0.3%; and, organic C (ppm)—6 to 30 ppm (c.f. Table 1, see also Rowe 1970). The abundance of these critical components at *A. infusa* aestivation sites indicate the scale of the bio-transfer of nutrients (Table 1).

Most published data on *A. infusa* aestivation derives from caves in NSW (e.g. Common 1954; Warrant *et al.* 2016) and these may be more favoured and productive than granite

boulder fields available in NSW (Table 1). Indeed, Common (1954) found moths on cave walls and ceilings at 17000 per m^2. In contrast, basalt boulder fields are a common type on Bogong and Hotham High Plains (Fig. 2) and appear to be as productive, if not more so, than NSW caves. Basalt boulder fields, as opposed to caves, provide both more geographic spread and vectors (diversity and amount) for the secondary bio-transfer of nutrients. The recent discovery that the moths navigate using magnetic fields (Dreyer *et al.* 2018) may also assist location of the basalt boulder fields and upslope flows which have high magnetic signatures (Morand *et al.* 2005).

Victorian alpine caves have not been well studied. However, since December 1967, Monika Baker (pers. comm., 2019) has annually recorded the presence of *A. infusa* in caves at three altitudes on Mt Buffalo. This remarkable record indicates that moths were always abundant in the higher caves and regularly used the lower caves. She found few moths in January 2018 and none in January 2019. The Mt Buffalo collapse—a 52-year record—mirrors observations on the Bogong High Plains documented here.

The *in situ* small mammal fauna respond to availability of *A. infusa*. The arrival of various Microchiroptera in the Alps coincides with moth arrival and is frequently observed when the moths emerge at sunset over summer. Although Green and Osborne (1994) noted that the quantitative extent of predation is unknown, our observations would suggest that *A. infusa* could be a major food item particularly for the medium to larger species (e.g. White-striped Free-tailed Bat, Eastern False Pipistrelle *Falsistrellus tasmaniensis*) and those common in adjacent Snow Gum woodlands, (e.g. Gould's Wattled Bat: Norris *et al.* 1983). Microchiroptera typically eat up to half their body weight per night. Churchill (1998) and Vestjens and Hall (1977) observed *A. infusa* as the major food component in the stomachs of Gould's Wattled Bat and Lesser Long-eared Bats in alpine NSW.

Consistently dense distributions of large bird species leave guano on site but also disperse nutrients through their droppings further afield. Similar to droppings of birds and Red Foxes, those of bat species would disperse nutrients in a secondary bio-transfer away from aestivation sites. We did not quantify the moth-derived guano dispersal by these species across the alpine area during the study, but contend it would be significant. In KNP, female feral pigs *Sus scrofa* have recently been shown to exploit alpine cave aestivation sites (Caley and Welveart 2018). *Agrotis infusa* have also transferred arsenic to the Alps (Green *et al.* 2001; Green 2008; Love 2010). The bio-transfer of nutrients (and contaminants) through seabird guano is environmentally very significant and well-studied (e.g. Ellis *et al.* 2006).

Microchiroptera, fox and avian predation would disperse nutrients further afield in a secondary bio-transfer. This dispersal of nutrients is important as a large proportion of the available plant nutrients of alpine soils remain concentrated in the top 5–10 cm of the soil profile (Rowe *et al.* 2017). Dust storms at 10 to 20 year intervals provide nutrients to soils in the Snowy Mountains; however, the contribution of aeolian dust and the *in situ* P cycle remains unclear (see Kirkpatrick *et al.* 2014). Other sources of nutrient input into the alpine landscape would come via rain (N) and weathering. We suggest that the annual moth migration, over millennia, has added substantial critical nutrients (e.g. P) to the alpine region.

In the globally unique 'soil' mountains of Australia a large proportion of the nutrients is concentrated in the surface 5–10 cm of the soil and the cycling of these nutrients is key to vegetation health/type and moisture retention capacity (Rowe *et al.* 2017; Kirkpatrick *et al.* 2014). From predator consumption, parasitism and adverse weather, Green (2011) estimated that the remains of a billion moths provided an annual 5000 gigajoules of energy to the Alps in New South Wales. Our study observed the same suite of predators. We support Green's conclusion that *A. infusa* makes a very significant nutrient input into the health of the alpine environment, its vegetation and water-holding capacity (see Rowe *et al.* 2017). The magnitude of the annual *A. infusa* migration helps avoid nutrient entropy in the alpine region.

The abundance of *A. infusa* outside caves helps explain much of the difference between the densities of *B. parvus* observed in Victorian basalt sites compared to the densities observed

in KNP (Mansergh and Broome 1994; Heinze *et al.* 2004; Fig. 3; Method A). At the KNP sites (see Methods section A) where *A. infusa* are not as abundant as at Mt Higginbotham (see Results section A), moths may still be the only prey item in female scats during breeding even if nightly movement to congregations is required (Smith and Broome 1992). *Burramys parvus* is relatively long-lived (females up to 12 years, males up to four years) (Mansergh and Broome 1994).Breeding/lactating female *B. parvus* and their young are *highly* dependent on the moths for nutrition. The collapse of the *A. infusa* population has had an immediate adverse effect causing starvation among *B. parvus* pouch young across its Victorian range (Australian Broadcasting Company 2019; Readfearn 2019; DH, pers. obs., 2016 to present). Disturbing though this is, the first-year recruitment to the breeding population remains consistent with a 35-year data set. At this stage, direct interventions in the population (e.g. supplementary feeding, removal/return) are to be avoided as this would further stress the wild population. Perverse outcomes are more likely than any perceived benefits (e.g. Weeks *et al.* 2017—for captive release). Continued absence of moths will lead to population decline, particularly where high densities of *B. parvus* are maintained by a huge abundance of moths (all Victorian basalt sites).

Although we did not monitor the micro-climate of the boulder fields, we have observed no adverse changes (except absence of *A. infusa*) in the aestivation sites of *A. infusa* that could help explain the recent population crash. Thus, the cause of the collapse would appear to derive from either interruption to the migration pattern or disturbance at the natal sites. Change in the strength and/or timing of winds that aid migration, NW spring and SE late summer, may have affected migration, particularly the latter. However, this would appear unlikely to have been the major cause of such a sudden collapse as moths can keep their direction even against wind (Warrant *et al.* 2016).

Radical environmental change at the natal sites is therefore suspected. Although much is known of cutworms in agricultural landscapes, knowledge of their pre-European habitat (and use of remnant vegetation) remains surprisingly sparse although they were common in saltbush country that has high seasonal dicotyledon abundance in the Riverina (Common 1954; Warrant *et al.* 2016; David Cheal, pers. comm., April 2019). There is a strong correlation between the range of *A. infusa* and the historical range of Yam daisies *Microseris* spp. in eastern Australia (see *A. infusa* cutworm map in Green 2011; Walsh 2016). Within that broad range the favoured habitat of both species (alluvial self-mulching soils) is more restricted. We suspect Yam daisies were an important part of *A. infusa* natal areas but with decline of the daisies the moths were able to exploit introduced pastures/crops and become a recognised pest. Drought refugia utilised by *A. infusa* (presumably moister, more fertile nodes in the landscape) would be a much smaller subset of their broader habitat, which itself is a subset of the national range.

Declines, but not collapse, in the abundance of *A. infusa* in the alpine region were observed throughout the Millenium Drought (1996 to mid-2010) that occurred across their natal sites, presumably because they were able to utilise drought refugia. Record rains in 2010–11, and consequent increase in moisture content and plant growth, may explain peak *A. infusa* numbers in 2013–14. Populations recovered from the Millenium Drought. Subsequently, drought conditions resumed and have intensified to the present (July 2019). Agriculture has intensified over these areas in the last 20 years, e.g. water use in cotton cultivation (Cotton Australia 2019). *Agrotis infusa* habitats in the self-mulching soils of the alluvial plains are favoured agricultural areas, with competition magnified in refugia areas during drought.

The declines in *A. infusa* abundance since the early 2000s correlate with drought conditions, land-use change and also the widespread adoption of neonicotinoids as a pesticide across natal areas (Nash *et al.* 2019). Available from the mid-1990s, neonicotinoids, a group of insecticides colloquially called *neonics*, are now the most widely used insecticides in the world, but only about 5% of the chemical remains in the plant—the remainder is dispersed and persists in the wider environment (Wood and Goulson 2016). In 2013, neonicotinoids were partially banned in Europe due to their adverse effects

on bees in certain crops (Wood and Goulson 2016). Wood and Goulson (2016) conducted a review of the effects on a range of biota, but unfortunately no studies were conducted on lepidoptera. They concluded that there is a growing body of evidence that persistent, low levels of neonicotinoids can have a negative impact on a range of free-living organisms. Neonicotinoid use in Australia was relatively stable from 1999 to 2016, but then jumped 34% in 2016–17 and has subsequently remained at these higher levels (Nash *et al.* 2019) (i.e. contemporaneous with the collapse of *A. infusa*). The Australian Pesticides and Veterinary Medicines Authority (APVMA) recommended residue monitoring of neonicotinoids in 2014, yet despite increased usage, no monitoring appears to have been undertaken to date (https//apvma.gov.au/pubcris). We strongly suspect that neonics are partially responsible for the collapse of the *A. infusa* population.

The recent rapid and unprecedented population crash of the annual *A. infusa* migration is a cause for national concern, particularly as it occurred after a peak year in 2014. There is evidence of worldwide decline in insect populations (Thomas *et al.* 2004); however, the dramatic collapse of the *A. infusa* population demands specific attention. The observed effects on endangered species (widespread starvation of *B. parvus* pouch young) and potential effects on the ecological health of alpine areas, including plant nutrients, vegetation health (and thus water-holding capacity), are now well documented. Are *B. parvus* pouch young 'canaries in the coal mine' that warn of dramatic environment change over huge areas of our agricultural landscape? The main scientific and conservation action should be concerned with the recovery of the *A. infusa* population. There is an urgent need for national action: for APVMA and Environment Australia to implement *their own* recommendations and for immediate additional research and monitoring of the *A. infusa* population in both their alpine summer habitats as well as in their natal habitats in agricultural areas to identify and protect these natal areas in terms of their native vegetation and drought refugia.

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This contribution is humbly dedicated to the late Alan Yen, a fine entomologist and a great supporter of FNCV and conservation in Victoria.

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EDITORS' NOTE

Moth Tracker

In September 2019, in response to concerns about the plight of critically endangered Mountain Pygmy-possums and the catastrophic decline of their major food source, Bogong Moths, Zoos Victoria launched its Moth Tracker app, a citizen science platform to report sightings of Bogong Moths.

To download the app and report or view recent sightings, go to <https://www.swift.net.au/mothtracker>.

Assessing consumption of Curiosity® feral cat baits by Blotched Blue-tongued Lizards

Michael Johnston[1], Frank Gigliotti[2] and Julie Trezise[3]

[1]Scientec Research Pty Ltd. Email: curiosity.catbait@gmail.com, PO Box 122, Warrandyte, Victoria 3113.
[2]Conservation Department, Phillip Island Nature Parks, PO Box 97, Cowes, Victoria 3922.
[3]French Island Landcare Group, Tankerton Post Office, French Island, Victoria, 3921.

Abstract
Invasive species management programs must consider the potential for impact on native species' populations that inhabit the proposed treatment area. The Curiosity® feral cat bait is intended to facilitate the broadscale management of feral cat populations in south-east Australia. Poison baits intended for feral cats must be surface laid, increasing potential exposure of non-target species compared to conventional predator control programs, which typically use buried baiting. The timing of control programs can be used to mitigate impacts on some non-target species by avoiding periods of predictable seasonal activity. This study sought to assess the potential for reducing the encounter and consumption of Curiosity® baits by Blotched Blue-tongued Lizards *Tiliqua nigrolutea*. Non-toxic baits were consumed by these lizards when they were active, but activity varied seasonally. Application of feral cat baits in south-east Australia is recommended to be undertaken in winter to reduce exposure of non-target species such as reptiles in the *Tiliqua* genus. (*The Victorian Naturalist* **136** (6), 2019, 203–207)

Keywords: *Tiliqua*, feral cat, poison bait, Curiosity®, non-target

Introduction

Feral cats *Felis catus* maintain self-sustaining populations in the wild in Australia where they impact wildlife through direct predation, disease transmission and resource competition (Department of the Environment 2015). The Curiosity® feral cat bait (Curiosity® Bait) has been developed to provide land managers of conservation reserves with a humane control tool that is attractive and palatable to feral cats but employs technologies to minimise impact on populations of native species. The bait contains a 78 mg para-aminopropiophenone (PAPP) formulation that is encapsulated in a tough acid-soluble polymer that forms a robust pellet. This is known as the Hard Shell Delivery Vehicle (HSDV) and is implanted within a moist meat food lure (Johnston *et al.* 2011; Johnston *et al.* 2014). Feral cats' foraging behaviour is based on identification of visual and auditory cues, but they will consume carrion, including baits, if encountered when hungry and the food is palatable. As feral cats rarely exhume buried food items, poison baits intended for this species must be surface-laid. This creates greater potential for exposure of non-target wildlife species than occurs in canid control programs, which typically use a buried baiting procedure.

Pen and field trials have demonstrated that the use of the HSDV in the meat lure is an effective technique to reduce the exposure of wildlife species to the toxicant (Marks *et al.* 2006; Hetherington *et al.* 2007; Forster 2009; Johnston 2010; Gigliotti 2011; Algar *et al.* 2017; Heiniger *et al.* 2018). This presentation technique exploits the differing dentition and feeding behaviour between feral cats and Australian native wildlife species. Feral cats are known to simply shear food items into manageable sizes before swallowing (Bradshaw 1992; Hilmer *et al.* 2010). It is common to find large, identifiable portions of prey species in their stomachs (Kutt 2012; McGregor *et al.* 2015; Johnston, pers. obs., 2012). In contrast, native wildlife species chew their food more thoroughly and tend to reject large hard items (Marks *et al.* 2006; Hetherington *et al.* 2007; Forster 2009; Johnston 2010; Gigliotti 2011; Algar *et al.* 2017; Heiniger *et al.* 2018). Buckmaster *et al.* (2014) assessed the potential for exposure to the encapsulated toxicant amongst all Australian native terrestrial vertebrate species. This study combined a desktop review along with results from *in vivo* observations for species considered to be likely to consume Curiosity® baits. Further studies were recommended to assess

the hazard that the baits present to other non-target species outside the existing dataset where there was any uncertainty about their risk to consuming Curiosity® Baits (Buckmaster *et al.* 2014). The current study was undertaken to inform the risk of bait consumption by Blotched Blue-tongued Lizards *Tiliqua nigrolutea* and potentially for other *Tiliqua* species.

Methods

Cage trapping programs for feral cats on French and Phillip Islands in Western Port, Victoria, have resulted in the capture of Blotched Blue-tongued Lizards as a non-target species. Trapping records over the period 2010–2018 were reviewed, with the capture rate of Blotched Blue-tongued Lizards compared across seasons; summer (December–February), autumn (March–May), winter (June–August), spring (September–November) and used as an index of activity. Trapping methods were consistent throughout the study period in terms of trap design, food lure provided and locations used, but trapping effort was biased towards cooler months when it was expected that feral cats were more responsive to the food lure provided in traps.

Field observations of the interactions of Blotched Blue-tongued Lizards with non-toxic versions of the Curiosity® bait were conducted in February–March 2018 on Phillip and French Islands (Fig. 1). Traps were opened at 25 sites on Phillip Island each morning within three hours of dawn and then closed before dusk. Traps on French Island remained open throughout the study, being checked within two hours of dawn and again prior to dusk, as this study was conducted in parallel with a feral cat trapping program.

The meat lure component of the Curiosity® bait was prepared from minced kangaroo meat and chicken fat. The meat was pH buffered to 7.5 to prevent premature deterioration of the HSDV, then formed into skinless sausages and air-dried (Johnston *et al.* 2014). Each bait was implanted with a non-toxic HSDV that contained Rhodamine B dye and placed at the rear of the cage trap (Fig. 2). Rhodamine B dye leaves a readily discerned mark on contact with moisture and/or skin tissue (Fisher 1999). A sheet of fabric was placed under all traps so that any uneaten portions of food and/or HSDV were retained. Captured lizards were removed from the cage, measured and inspected for pink-coloured staining around the mouth that would indicate exposure to the Rhodamine B dye. A small identifying mark, located behind either front leg, was created with a felt tip pen to assist with the identification of recaptured individuals. The lizards were then released into nearby vegetative cover. The amount of bait material consumed by the lizards and the condition of the HSDV (intact/damaged/not found) were documented. A fresh Curiosity® bait (including non-toxic HSDV) was supplied when the trap was reset.

Results

Historical trap records from both island sites, comprising 99 816 trap days, indicated 406 individual captures of Blotched Blue-tongued Lizards over the study period (2010–2018). The majority (63%, n=256) of these captures occurred in summer despite this season recording the least trapping effort (Fig. 3). During the winter season, three lizards were captured over a total of 50 620 trap days (0.005% trap success). Greater numbers of lizards were captured in autumn (65) and spring (82) achieving an equivalent trap success of 0.3%. By contrast, considerably less trapping was undertaken in summer (~8000 days), but resulted in significantly greater trap success (3.7%). A chi-square test of independence in R (R Core Team 2019) demonstrated a significant difference in capture rates of *T. nigrolutea* between seasons $\times^2 = 2073.3$, df = 3, $p<0.001$.

The field observations comprised 502 and 511 trap days on Phillip and French Islands respectively. A total of 30 adult Blotched Blue-tongued Lizards were trapped, with four individuals caught twice (Table 1). Baits were either wholly or partially consumed in 73% of presentations, with the HSDV consumed in 86% of these (Table 2).

Discussion

Blotched Blue-tongued Lizards are known to be generalist omnivores, consuming invertebrates, snails, soft plant material such as flowers, and carrion (Ehmann and Strahan 1992; Shea 2006; Robertson and Coventry 2019). Our data

Fig. 1. Locations used to capture Blotched Blue-tongued Lizards during this study.

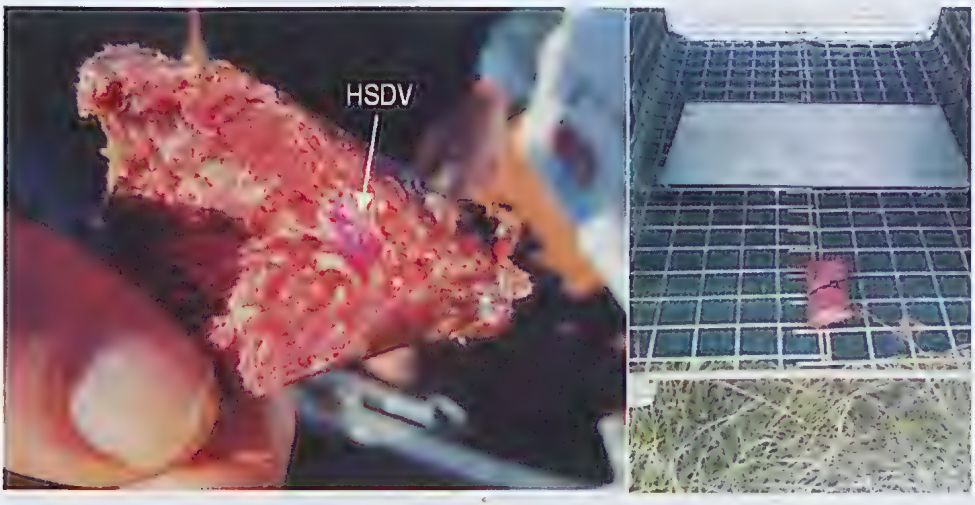

Fig. 2. A Curiosity® bait with the Hard Shell Delivery Vehicle (HSDV) implant and method of fixing in a cage trap.

Table 1. Summary of capture records.

Species	Phillip Island	French Island	Total
Blotched Blue-tongued Lizard *Tiliqua nigrolutea*	18	12	30
Cat *Felis catus*	nil	5	5
Echidna *Tachyglossus aculateus*	5	3	8
Long-nosed Potoroo *Potorous tridactylus*	nil	1	1
Rabbit *Oryctolagus cuniculus*	nil	1	1

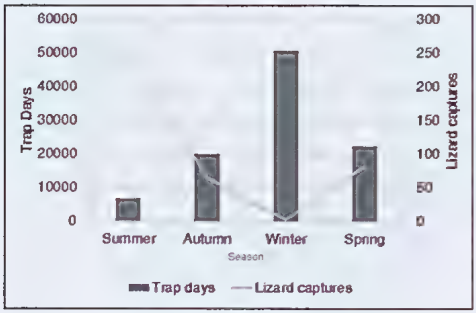

Fig. 3. Capture of Blotched Blue-tongued Lizards compared with trap effort over the period of 2010–2018.

Table 2. Summary of Curiosity® bait consumption and HSDV recovery in Blotched Blue-tongued Lizard trials.

	No. of presentations	HSDV recovered
Whole bait consumed	14	2
Partial bait consumed	8	1
No bait consumed	8	8

demonstrate that Blotched Blue-tongued Lizards will consume the Curiosity® bait including the HSDV when they encounter it. The dentition and masticatory behaviour in Blotched Blue-tongued Lizards does not lead to similar HSDV rejection behaviour that has been observed in mammals (Marks *et al* 2006; Hetherington *et al.* 2007; Forster 2009; Johnston 2010; Gigliotti 2011; Algar *et al.* 2017; Heiniger *et al.* 2018) and birds (Gigliotti 2008). Other *Tiliqua* have similar diets and behaviours (Shea 2006), and will consume Curiosity® baits if they encounter them.

There are limited data on the susceptibility of Australian reptiles to PAPP, with small-scale pen trials conducted only with Lace Monitors *Varanus varius* and Rosenberg's Goanna *V. rosenbergi*, indicating a high susceptibility to the compound (summarised in McLeod and Saunders 2013). No data exist describing the tolerance of *Tiliqua* to PAPP. We assume that *Tiliqua* have a similar tolerance to the varanids tested and that one Curiosity® bait would contain a lethal dose if ingested. In this case, we suggest that the lizards that consumed the HSDV would have died had toxic PAPP doses been provided.

The seasonal difference in the activity of reptiles such as Blotched Blue-tongued Lizards in the south-east of Australia is well known (Cogger 2014; Robertson and Coventry 2019). This is reflected in the variable capture rate of Blotched Blue-tongued Lizards during feral cat trapping programs undertaken on Phillip and French Islands. These programs have mostly been undertaken during the cooler months as this is when feral cats are more likely to demonstrate interest in the food lure provided in the cage traps.

The exposure hazard of *T. nigrolutea* to Curiosity® baits can be largely mitigated by exploiting the observed seasonal behaviours of this species at this latitude. Restricting the application of Curiosity® baits to cooler months when these animals are minimally active is recommended. In south-east Australia, this would typically be during late May–July. It is unlikely that baits laid at this time would subsequently present a hazard when Blotched Blue-tongued Lizards become more active as daily temperatures increase in Spring, due to natural degradation and consumption by other species, particularly invertebrates.

Previous work by Jessop *et al.* (2013) monitored removal of non-toxic Curiosity® baits from stations using trail cameras during summer 2010–11 in eastern Victoria. In that study, Lace Monitors *Varanus varius* were responsible for removing 7% of the 1686 supplied baits. Greater bait take was observed on days of elevated temperature, but notably Monitors were active and removed baits during cooler summer days of 17 °C (Jessop *et al.* 2013).

A precautionary approach is recommended for land managers who intend to use Curiosity® baits, to avoid application of baits during periods when non-target reptile species, such as *Tiliqua* sp., are expected to be active and consume baits. A hazard assessment considering potential impacts on populations of non-target species is recommended during the planning stages of Curiosity® baiting programs.

Acknowledgements

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Possible cooperative feeding by Grey Butcherbirds *Cracticus torquatus*

I knew Grey Butcherbirds *Cracticus torquatus* (Fig. 1) occurred in the Croydon area of Victoria, but had not seen one in the vicinity of my home until May 2018. They frequently skewer uneaten food on twigs or hang it in forks of tree branches, thus their common name. I had just provided a tiny piece of low fat, hard cheese to my 'co-owners' of the back and front yards, four Australian Magpies *Cracticus tibicen*. These tiny snacks are provided irregularly and the Magpies are not dependent on the human residents of the property, although the male, in particular, makes good use of my activities. When I garden, this Magpie is usually there, and snatches any worm I may disturb. When I chop wood, he stands by my feet and pounces on any grub revealed by the splitting of wood. On this particular occasion, I was turning to go inside after giving the Magpies a snack when I saw a Grey Butcherbird alight on the nearby side fence. I offered a snack, but the bird was very timid and flew away. This was my first encounter with the Butcherbird.

Some days later, I again gave the Magpies a snack and saw the Butcherbird on the side fence. Not wishing to frighten it, I turned to go inside, but it flew to a hanging basket on my back verandah, where it stared at me until I threw a tiny piece of cheese onto the ground. It then scanned the area carefully, I presumed for danger, before it darted down and flew off with the cheese.

This Butcherbird visited rarely, always following a visit by the Magpies, and it always flew off with the cheese. However, in late July, it went to the oak tree beside the back verandah and ate its snack on a low branch while I was watching. It then looked at me as if seeking another piece. I considered this behaviour unusual and gave it a second piece, using the coldness of the morning to salve my conscience. After again scanning the area in all directions, it dived down, took the cheese and flew off. I wondered whether it was feeding its young, or mate as the species is known to do (Burt 1996; Johnson 2003; Ligon and Burt 2004). It always flew off in the direction of a tall *Eucalyptus* tree about 250 m away and close to a strip of trees alongside the railway and Silcock Reserve. This became its usual behaviour during its infrequent visits.

Another time, I had gone inside after giving the resident Magpies a snack in response to their carolling to let me know they were there. I heard what I at first thought was a Magpie singing so ignored it, as I thought it was being greedy, but, as the singing continued I realised there was something different about it and went out to investigate. I was pleasantly surprised to find it was my Butcherbird singing a most beautiful song while sitting on his usual perch on the oak tree (I was now able to sex it. Both sexes have a white loral spot but, in the female, a white line extends backwards from the spot under the eye. The male also tends to be a little larger and its colouration slightly brighter [Johnson 2003]). Upon sighting me, he flew to the hanging basket and waited for food. I had to go back inside for this and feared he might leave, but he waited, and when I threw the morsel of cheese on the ground, he carefully looked in all directions, dived to take the cheese back to his perch, ate it and then 'requested' a second piece, which he took before flying off in the usual direction. I wondered whether the Butcherbird had learnt from the Magpies to sing for a breakfast snack.

Yet another time, late in the breeding season, I came out of the back doorway and the Butcherbird flew from the oak to the hanging basket, stared at me and waited for his snack. This was mid-morning and the Magpies were not present. The Magpies normally came early in the morning, if they visited. We went through the usual routine, but instead of darting down for his snack the Butcherbird checked for danger, turned its whole body 180 degrees, looked up into the oak tree and made three short, soft, throaty calls, the last a fraction longer than the first two. A female Butcherbird darted down from higher in the oak, took the cheese and flew towards the eucalypt that the male always flew to. The male then turned again, looked at me and waited for another piece of cheese. When I

Fig. 1. Grey Butcherbird *Cracticus torquatus.*

threw it down, he again carefully looked in all directions, dived down, picked it up and flew off after the female. This occurred on three more occasions; however, I heard calling only the first time. The other times he turned and looked at the female, which responded by diving down and carrying the snack away, i.e. it appeared to me he was signalling the female to let her know it was safe. I have not seen a record of this behaviour in the literature. Grey Butcherbirds display cooperative breeding (Burt 1996; Johnson 2003; Ligon and Burt 2004), where the mate and/or one or more of the previous season's young feed the chicks and, in some instances, the bird sitting on the eggs (Johnson 2003). I wondered whether this signalling to let the female bird know it was safe was another form of cooperative behaviour.

After the end of November 2018, I saw neither the pair nor the male Butcherbird on its own until, late in June 2019, the male came back. I have seen it only once this year. However, another male Grey Butcherbird now visits the front yard infrequently, and has done so since May. He too comes and goes to a large *Eucalyptus* tree but always from the opposite direction to my first Butcherbird. This second Butcherbird is slightly larger and the two behave quite differently. The first male never ventured into the front yard and stayed a greater distance from me than the second, which would allow me to walk past it.

The second male first came on his own, but then brought a female. Three times I have seen the same behaviour that occurred with the first pair of Butcherbirds, where the male waits for a piece of cheese to be thrown down and then alerts the female. With the second pair, I have heard the male call the female from her higher branch to collect the cheese, but it gave only a single short, soft, throaty call in each of the three instances. Again, the male always carefully examined the immediate area before calling the female.

This pair visits more frequently, both together and individually, but not regularly. At first they came only following the Magpies' chorusing, but now come either tailing the Magpies or during mid morning. At the time of writing (the end of June, 2019), I have yet to see whether this

male will take the cheese back to what I presume is their nesting tree when, again presumably, there will be eggs in the nest.

Feeding of birds in Australia, generally, is not recommended and a number of websites provide lists/factsheets of the detrimental effects this practice has on birds; e.g. Birdlife Australia; City of Monash; Knox City Council; Wildlife Information, Rescue and Education Service (WIRES). This, generally, is supported by veterinarians, e.g. Brisbane bird and exotic animal vet Deborah Monks (Renault 2018). However, the growing scientific literature on the effects of feeding wild birds, (e.g. Ishigame *et al.* 2006; Jones and Reynolds 2007; O'Leary and Jones 2005; Reynolds *et al.* 2017; Wilcoxen *et al.* 2015) demonstrates both positive and negative effects, and that birds do not become dependent except in extreme situations (O'Leary and Jones 2005; Wilcoxen *et al.* 2015). Chapman (2015) reports that 63% of Australian households feed wild birds. It is becoming accepted that people will continue to feed wild birds and there are calls that we should be discussing rather than demonising the practice (Jones 2016; Convery 2017) and that advice on feeding should be based on scientific rigour (Ishigame *et al.* 2006; Jones and Reynolds 2007; Wilcoxen *et al.* 2015). People feeding birds could participate in Citizen Science projects and contribute to large-scale, multi-faceted projects in this field (Jones and Reynolds 2007).

I hesitated in writing this article, due to a possible backlash for succumbing to the overtures of 'my' Magpies and Butcherbirds. I am not supporting bird feeding with this article, and have warned people of the possible dangers, yet I am one of the 63% of Australians who do so. Neither should publication of this Naturalist Note suggest *The Victorian Naturalist* or Field Naturalists Club of Victoria support feeding wild birds. The Note was written simply to share with others a possible form of cooperative feeding by the Grey Butcherbird.

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Maria Gibson
Field Naturalists Club of Victoria
PO Box 13
Blackburn, Victoria 3130

Are Noisy Miners becoming more game with humans?

Noisy Miners *Manorina melanocephala* are one of the most common passerines in metropolitan centres in south-eastern Australia (Barth *et al.* 2015). As a result, few days have passed without my seeing or hearing at least one. They are reputed for their tendency to mob other animals larger than themselves in a flock or singly (Barati *et al.* 2016; Val *et al.* 2018; Fig. 1). These behaviours are often combined with their distinctive vocalisations (Kennedy *et al.* 2009), which easily attract attention. I've watched Noisy Miners repeatedly charge into the backs of roosting Powerful Owls *Ninox strenua* (Mo *et al.* 2016b) and mob adult Lace Monitors *Varanus varius* descending tree trunks toward their nests (Mo 2019). Both are known predators of the birds (Mo and Waterhouse 2015; Mo *et al.* 2016a).

Fig. 1. A Noisy Miner vocally launching from a perch to mob other birds.

In my casual observations of Noisy Miners, watching them mob birds and other animals has been common. However, observations of aggressive swooping towards humans are rare. Generally, they perch on branches and vocalise intensely when humans stray close to their nests. In November 2013, I was surprised to find a Noisy Miner in North Parramatta, NSW, appearing to follow me down the street, flying from branch to branch while making its characteristic mobbing call. It continued over a distance of at least 20 m before swooping at me from in front. I estimate it came within 5 m of me, which prompted me to search for a nest. I didn't find one, but it was possibly hidden in the thick canopy of an ornamental street tree.

For five years I didn't make any comparable observations. In September 2018 I was photographing wildlife in the EG Waterhouse National Camellia Gardens, Caringbah South, NSW, when Noisy Miners were feeding nearby. As I meandered through the gardens, I reached a location where the birds' mobbing calls became increasingly erratic. I was standing close to a low bush when the increase in mobbing calls alerted me to a nest, which was no more than 2 m from the ground. At least five Noisy Miners descended in the branches around me and vocalised. A pair of them then began to swoop at me, to within 20 cm. This happened seven times before I decided to move on. They may have swooped a few more times while I moved away. The last swoop they made occurred more than 20 m from the nest. During this event, I noticed the bird approaching when I turned around to see how far I was from the original position.

In April 2019, I revisited this site and heard the Noisy Miners becoming more vocal near the same bush. The nest from the previous year showed signs of deterioration and was not being used. Three metres away, Noisy Miners were returning to feed chicks at an active nest (Fig. 2). As I approached, both birds swooped me to within 20 cm. Sometimes they appeared to swoop almost in unison, with one bird swooping first and a second bird swooping as the first bird flew away. Most swoops were from behind or the side. When they swooped from behind, they made contact with my back and head at least six times.

In the same month, I noticed Noisy Miners during a walk around Darling Harbour, Sydney central business district. One bird quietly swooped a person in front of me from behind. The swoop appeared to be within approximately 10 cm of the person's head; however, this was apparently unnoticed. The bird flew on to an overhanging branch, at which time it started to vocalise. It held this position for two minutes as

Fig. 2. Two Noisy Miner chicks on a nest with the adult bird close by between mobbing attacks on passers-by.

I stood still, watching it. The bird then left the perch and swooped at me from the front. At the closest distance, the bird may have been 20 cm from my head. I looked around for a nest but didn't find one, and attracted no further attention from the bird.

Despite regularly seeing Noisy Miners, until 2013 I had never observed them dive-bombing people. Moreover, I didn't see this behaviour repeated until recently. This raises the question whether the birds' continuing habituation to metropolitan centres has led to some individuals attempting closer contact when mobbing. Undoubtedly, Noisy Miners vary in their approachability, depending on location. In most places, Noisy Miners will merely approach people offering handouts from a distance. However, where people regularly feed waterfowl and other birds, given the chance Noisy Miners often take food from the hand. Certainly, all the locations reported here fall into this latter category. However, I have visited these locations over many years and have not seen Noisy Miners swooping people there until recently.

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Matthew Mo
Email: matthew.sk.mo@gmail.com

Australian Bird Names: Origins and Meanings. Second Edition

by Ian Fraser and Jeannie Gray

Publisher: *CSIRO Publishing, Clayton South, Victoria; 2019. xviii, 347 pages, paperback, b&w illustrations. ISBN 9781486311637. RRP $54.99*

Much has happened in the ornithological world since 2013, when the first edition of this book, titled *Australian Bird Names: A Complete Guide*, was published. Fifty-five species of vagrants have been added to the national list, and a further 21 species have been 'created' by taxonomic splitting of resident species. While not intended as an authoritative checklist of Australian birds, this second edition is a thoroughly researched, entertaining—and often amusing—account of the meanings and stories behind these birds' names.

Book contents include Introduction to the First Edition, Introduction to the Second Edition, Non-Passerines, Passerines, References, Index of common names and Index of scientific names. The illustrations are taken from Silvester Diggles' *Companion to Gould's Handbook; or, Synopsis of the Birds of Australia*, published in Brisbane in 1877 by Thorne and Greenwell. The only alternative at the time, John Gould's *Birds of Australia*, was very expensive, and Diggles believed that Australians should have an affordable guide to their country's birds.

The Introduction to the Second Edition includes informative sections on the naming of birds, how common and scientific names have been derived, the process of naming a bird, and why names change. There is also historical information about lists of Australian bird names including: the contributions made by prominent ornithologists from the eighteenth century onwards, checklists produced by the Royal Australasian Ornithologists Union (now Birdlife Australia), Birdlife Australia's *Working List of Australian Birds*, and international lists such as the *IOC World Bird List*, which are widely used today. The organisation of the book is explained, followed by a section about translations, pronunciation and derivations. Here Fraser and Gray state 'We have … used free, and sometimes creative, translations, especially where the author's thinking was not made clear. Where we have speculated, we have been careful to say so' (p. xvii).

The bulk of the book is packed with truly fascinating details about origins and meanings of bird names. Here you will find stories from Greek mythology and accounts of early explorers, naturalists, ornithologists, zoologists, and the many people involved in collecting birds and creating names for them. A few racehorses also get a mention! Some names are apt, for example *Eudyptes chrysocome* 'good diver with golden hair' for Southern Rockhopper Penguin; some, such as the genus name *Gerygone*,

meaning 'child of song,' are quite beautiful; some sound rather insulting, e.g. *Anous* 'stupid bird' for the Noddies ('noddy' is an old English word meaning 'simpleton'); some seem a little odd, e.g. *Melanodryas vittata* 'black banded tree-nymph' for Dusky Robin; while *Xema*, the genus name created by William Elford Leach for Sabine's Gull (pp. 77–78), is apparently totally meaningless!

Most birds are or have been known by several different common names, for example Laughing Kookaburra, a species that 'has possibly attracted more folk names ... than any other Australian bird' (p. 137), and White-fronted Chat, a bird that 'has attracted a wealth of names' (p. 195). By contrast, the Black Swan is 'notable in having had, apparently, no other names' (p. 10), while for the Large-billed Scrubwren, 'Except for Gould's Large-billed Sericornis, ... no other name has ever been needed' (p. 213). In some cases there is no known explanation for a name, e.g. 'Devil-bird' for both Grey Fantail and Yellow-throated Scrubwren.

Having lived in Tasmania for 20 years, I was interested to discover that one of the common names for the Tasmanian Nativehen is 'Turbo Chook', 'an affectionate Tasmanian folk name, for its impressive burst of speed'. This bird is also known as 'Narkie', 'probably for the hard nasal aggression calls and somewhat squabbly nature, though it could also be from an Indigenous language' (p. 46). In any case, once heard, never forgotten!

Common names and scientific names are listed in separate indexes. Names of both genera and species are listed in the Index of scientific names, making it is easy to look up a species if the genus name can't be recalled. A random check revealed occasional errors in the Index of common names. For example, Grey Shrike-thrush (p. 240) is listed as being on p. 229, and Grey Butcherbird (p. 229) on p. 228. There are software packages that eliminate this type of problem, and one could be used in producing future editions.

The wealth of meticulously researched information presented in this book makes it an essential reference for anyone keen about birds and words, and a very welcome addition to ornithological literature.

Virgil Hubregtse
6 Saniky Street
Notting Hill
Victoria 3168

One Hundred and One Years Ago

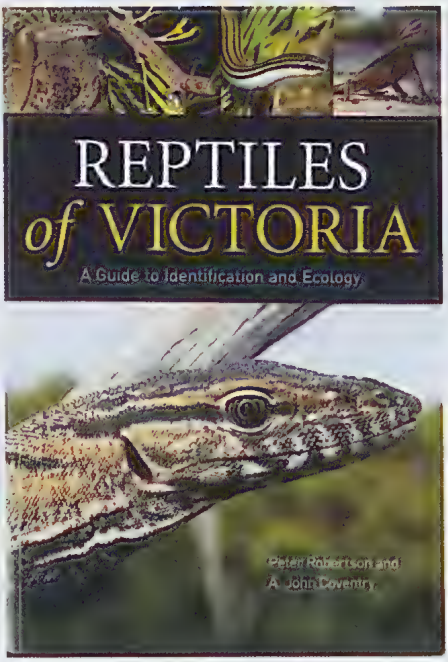
RE-NAMING AUSTRALIAN BIRDS: IS IT NECESSARY?—Mr. A. J. Campbell, C.M.B.O.U., &c, has issued in pamphlet form, an address delivered at a conversazione of the Royal Australian Ornithologists' Union on 3rd July last. The object of the address is to call attention to the hopeless confusion into which the list of Australian birds is being thrown by those energetic literary ornithologists who are engaged in searching obscure and scarce literature for chance references and earlier names for many of our birds. He contends that the greater number of Gould's names are scientifically correct, and should remain as the basis of an Australian bird-list. Many of these names have been in use for upwards of seventy years; why replace them with names which, in many instances, are totally inapplicable? And we think most naturalists will agree with his contention. Mr. Campbell promises, after the war, a volume descriptive of his experiences in various parts of Australia, which should have a ready sale.

From *The Victorian Naturalist* **XXXV**, p. 84, September 5, 1918

Reptiles of Victoria: A Guide to Identification and Ecology

by Peter Robertson and A John Coventry

Publisher: *CSIRO Publishing, Clayton South, Victoria; 2019. 332 pages, paperback, colour photographs. ISBN 9780643093935. RRP $49.99*



This book is one I have looked forward to for many years. It has been worth the wait. The 332-page book not only gives the reader detailed information on the features and identification of Victorian reptiles but also provides much more than your typical field guide. It also provides a general overview of the ecology for each species. All 123 native, vagrant and introduced reptiles are covered in detailed accounts. A further five species, which occur near Victoria and are not yet recorded officially, are covered in a small section at the end of the species accounts.

The book is well laid out, in a logical manner, with the first section providing an introduction, information on reptilian biology, biogeography, habitats and distribution, and a classification overview. The second section covers the species themselves. Lastly, there are sections for first aid, Victorian wildlife regulations, a comprehensive glossary and bibliography. There is a brief overview of each order and family with a clear dichotomous key following each account.

Each genus also gets an overview that provides general information, including the total number of species, distribution outside of Victoria, and basic habits. Recent name changes at genus level are also given. Following this overview, there are dichotomous keys that incorporate photographs and excellent diagrams showing key features and characters for each genus with more than one Victorian taxon. The exception to this is the section dealing with Beaked Geckos *Rhynchoedura*, which addresses the Victorian animals as a single but uncertain species. The genus was the subject of a review in 2011 (Pepper *et al.* 2011) and, while the paper provides morphological characters to split each of the species, these require close examination of scalation and pattern, and specifically state that without distribution data the characters in south-eastern Australia are potentially unreliable. The uncertainty in this case results from the fact that the paper did not examine Victorian specimens, so the identity of the Victorian taxon is unknown at this time.

The individual species accounts are comprehensive, with sections on identification, distribution and habitat, biology, recent synonyms, similar species and conservation. The identification section has important characters in bold text to allow the reader to focus on important diagnostic characters. Likewise, important habitat requirements are also highlighted. The distribution maps are excellent, as is the section on biology. The section on 'recent synonyms' is good, but can be confusing, considering some names regarded as recent have not been

used for more than 35 years. The conservation section is specifically for Victoria; while this is important, it would have been nice to see the federal status in addition to the state-based assessment.

There are some very minor factual errors, including the distribution of Death Adders in Asia (they extend to the island of Obi, Indonesia, not Borneo), and the assertion that all Australian native blindsnakes are in the genus *Anilios* (the exception, *Ramphotyphlops exocoeti* occurs on Christmas Island). There are a few errors in the numbers of species currently recognised, due to relatively recent taxonomic revisions. There are some differences in the taxonomy and nomenclature adopted in this work from that of other recent publications; however, this does not detract from the book itself. The only other minor criticism is that it would have been nice to see diagrams illustrating first aid for snake bite.

The images used are of a very high standard, with multiple images of most species. Having the locality information is a worthy addition. It was particularly nice to see images in life of two Grassland Earless Dragons *Tympanocryptis pinguicolla*, a species that is likely extinct.

The price of $49.99 is surprisingly low for a book of this size and quality; low enough that I am sure many people will end up getting both a field and home copy.

The book is an excellent, important addition to a library for anyone interested in Victorian fauna, let alone reptiles. Much like the author's previously co-authored work, *Snakes of Victoria* (1991), this new book, covering all of Victoria's reptiles, is sure to become a classic.

Reference

Pepper M, Doughty P, Hutchinson MN and Keogh JS (2011) Ancient drainages divide cryptic species in Australia's arid zone: Morphological and multi-gene evidence for four new species of Beaked Geckos (*Rhynchoedura*). *Molecular Phylogenetics and Evolution*, **61**, 810–822.

Scott Eipper
Nature for You
PO Box 529
Marsden, Queensland, 4132

A Guide to Crickets of Australia

by David Rentz and You Ning Su

Publisher: *CSIRO Publishing, Clayton South, Victoria; 2019. 416 pages, softback.*
ISBN 9781486305-063 RRP $49.99

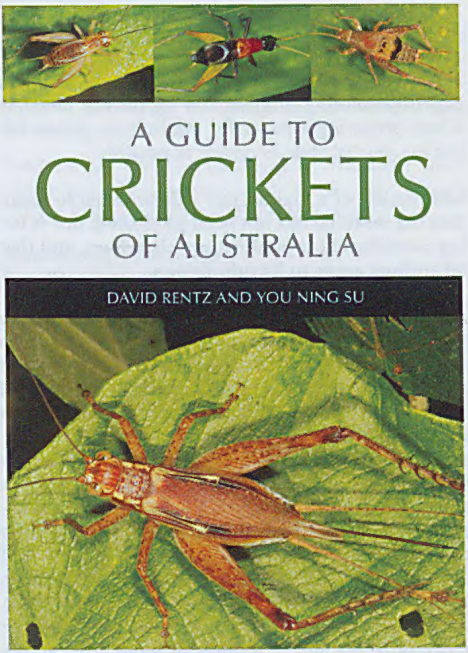
Most Australians are familiar with the characteristic chirpings of crickets—in gardens, parks and bush, their calls are reassurance of the wellbeing of their environments. Yet, few people are aware of either the variety of these insect musicians, or that almost all our cricket species occur nowhere else in the world. That richness was brought forcefully to the attention of entomologists after two visiting American experts spent a year travelling through Australia collecting crickets and recording their individual songs. The resulting monograph (Otte and Alexander 1983), until now the 'bible' for cricket enthusiasts in our region, reported 492 species, 376 of them described as new. However, even then, it was recognised that numerous other species occurred. That situation persists—disarmingly, the authors of this splendid new guide note that they were 'pleasantly surprised when we discovered a species that we could positively identify as a "named" one!', and tentatively suggest that the fauna may include twice the number of species recognised in that earlier monograph.

This book, as with others by David Rentz in the same series, is a 'tour de force', with his considerable expertise here augmented by that of another expert orthopterist, You Ning Su. It is attractive in appearance, encapsulating a wealth of information (much of it original), with abundant and excellent colour photographs and other illustrative material. Its background information on a wide range of topics is sufficient to capture and foster interests among a broad readership and inform already well-versed

others. The book also avoids dense or overly technical language, and is easy to read. Naturalists will appreciate the care taken to present such a readable and authoritative guide.

The book deals with 92 genera of Australian crickets, defined here as members of the superfamilies Grylloidea (true crickets) and Gryllotalpoidea (mole crickets, ant crickets). It thus excludes several groups popularly known as 'crickets' but not truly related to them: the 'raspy crickets', 'king crickets' and 'pygmy mole crickets'. A broad systematic overview of the two focal groups occupies most of the book (about 300 pages). The preceding more general chapters give much background information on cricket biology, the history of cricket study in Australia (with vignettes of key personnel: 'Australian cricketers'), and an account of the above-mentioned American expedition (with a map showing locations of the more than 900 collecting stops over about 73 600 km of travel). They also include much biological background on habitats, life histories, methods for collecting and processing specimens, an account of cricket morphology to clarify terms used in the descriptive sections, and the roles of crickets in human culture. Finally, a section about crickets as food and feed is a highly topical subject as interest in entomophagy continues to increase. Almost all pages are adorned with clear and relevant colour photographs.

Those illustrations continue, and come to the fore, in the systematic account, which many people will use primarily to identify specimens they have encountered. The authors recommend the approach of 'thumbing through' the book until a species similar to the target is recognised from the illustrations, and then checking it against the more technical structural details provided, as well as the distribution maps given for each taxon. Sonograms are also given for many species, and the text encapsulates the distinguishing features and known biology of each taxon. This general approach to identification largely obviates the need for formal keys, of which only a few are provided, to facilitate separations within particular complex groups: species-level keys for many insect groups can be frustrating to use when many species are still undescribed and simply will not fit! I tried a few identifications from the 'thumbing



approach'. They seemed to work well, and I found the tabular character state summaries provided for comparisons of related or similar species also very useful.

A full checklist of described Australian crickets, a useful glossary, some helpful information sources, references, some food recipes (for both people and for rearing crickets), and an index complete the work.

A Guide to Crickets of Australia is a very welcome addition to this series of guides, of interest and value to naturalists of all persuasions, as well as being a notable addition to our scientific awareness of this significant group of insects in Australia. It is excellent value and recommended highly as an authoritative, attractive and, above all, reliable and useful guide, which should do much to stimulate wider interests in our remarkable orthopteran fauna.

Reference

Otte D and Alexander RD (1983) *The Australian Crickets* (Orthoptera: Gryllidae). *Monograph no. 22.* (Academy of Natural Sciences of Philadelphia: Philadephia, USA)

TR New
Department of Ecology, Environment and Evolution, La Trobe University, Melbourne, Victoria 3086.
Email: T.New@latrobe.edu.au

Guidelines for authors—*The Victorian Naturalist*

December 2019

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Submission of a manuscript will be taken to mean that the material has not been published, nor is being considered for publication, elsewhere, and that all authors agree to its submission.

Authors may submit material in the form of Research Reports, Contributions, Naturalist Notes, Letters to the Editor and Book Reviews. All Research Reports and Contributions are peer reviewed by external referees. A ***Research Report*** records the results of a structured study that employs methods and analyses designed to answer a question. It is written in the third person, and in a form that includes an abstract, introduction, methods, results and discussion. A ***Contribution*** answers a question through research, which is not necessarily new, e.g. it could be a literature review used to provide the answer, or make a comparison. The scope of a contribution is broad, in order to encourage material on a wide range of topics and in a range of styles. This allows inclusion of material that makes a contribution to our knowledge of natural history but for which the traditional format of scientific papers is not appropriate. ***Symposia papers*** are the published form of papers presented at FNCV symposia and will be reviewed inhouse. ***Naturalist Notes*** are generally short, personal accounts of observations made in the field by anyone with an interest in natural history. These notes also may include reports on excursions and talks, where appropriate, or comment on matters relating to natural history. ***Letters to the Editor*** must be no longer than 500 words. ***Book Reviews*** are usually commissioned, but the editors also welcome enquiries from potential reviewers.

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Research Reports and Contributions must be accompanied by an ***abstract*** of not more than 150 words. The abstract should state the scope of the work, give the principal findings and be sufficiently complete for use by abstracting services.

Keywords are included following the abstract in Contributions and Research Reports. A maximum of five terms will be used.

References are cited chronologically in the text by author and date. All references in the text must be listed at the end of the paper in alphabetical order. Entries in this list must correspond to references in the text.

An electronic version and one hard copy of the manuscript are required upon resubmission after referees' comments have been incorporated. Documents should be in Microsoft Word. **The bibliographic software 'EndNote' should NOT be used.**

Abbreviations

The following abbreviations should be used in the manuscript where appropriate (italicised as indicated): *et al.*; unpubl. data; pers. obs.; pers. comm. **(each followed by a date as appropriate)**; 'subsp.' for subspecies.

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Papers reporting work that required permits should quote the appropriate permit type and numbers.

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For further information on style, write to the editors, or consult the latest issue of *The Victorian Naturalist* or most recent edition of *Style Manual for Authors, Editors and Printers* (John Wiley & Sons: Milton, Qld).

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Leigh J, Boden R and Briggs J (1984) *Extinct and Endangered Plants of Australia*. (Macmillan: South Melbourne).

Lunney D (1995) Bush Rat. In *The Mammals of Australia*, pp. 651-653. Ed R Strahan. (Australian Museum/Reed New Holland: Sydney).

Phillips A and Watson R (1991) *Xanthorrhoea*: consequences of 'horticultural fashion'. *The Victorian Naturalist* **108**, 130-133.

Smith AB (1995) Flowering plants in north-eastern Victoria. (Unpublished PhD thesis, The University of Melbourne).

Wolf L and Chippendale GM (1981) The natural distribution of *Eucalyptus* in Australia. Australian National Parks and Wildlife Service, Special Publications No 6, Canberra.

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BoM (2014) Climate data online. Available from: <http://www.bom.gov.au> (accessed 14 January 2014). (Bureau of Meteorology: Melbourne).

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Mammals – Menkhorst PW and Knight F (2011) *A Field Guide to the Mammals of Australia*. 3rd edn. (Oxford University Press: South Melbourne).

Reptiles and Amphibians – Cogger H (2014) *Reptiles and Amphibians of Australia*. 7th edn. (CSIRO: Collingwood, Victoria).

Insects and Marine Creatures – ABRS: <http://www.environment.gov.au/biodiversity/abrs/online-resources/fauna/index.html>

Birds – Christidis L and Boles WE (2008) *Systematics and taxonomy of Australian birds*. (CSIRO: Collingwood, Victoria).

Plants – VicFlora (2015). Flora of Victoria, Royal Botanic Gardens Melbourne, <http://data.rbg.vic.gov.au/vicflora>, last accessed (insert relevant date).

Please submit manuscripts and enquiries to:

The Editor
The Victorian Naturalist
PO Box 13
Blackburn, Victoria 3130

Phone: +61 (03) 9877 9860
Email: vicnat@fncv.org.au
Web: www.fncv.org.au

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